*PROFESSOR AGASSIZ'S SOUTH AMERICAN EXPEDITION**

II.

FOR reasons which I will explain presently, I would mention especially pebbles of a red porphyry, and others of a green compact epidote, as common in the Port San Antonio formation. The position of the Bay of San Mathias, its great length, and more particularly the depression or denudation at Port San Antonio, suggest the probability that the Rio Negro once poured its waters into this large gulf instead of opening directly into the ocean. I should add that while erratic pebbles occur in such abundance at San Mathias Bay, there are no hard rocks in place upon which the peculiar marks of glacial action could be perceived. Nor would these stratified banks of pebbles, even though unquestionably connected with the drift, afford in themselves any unmistakable evidence of glacial derivation.

As time and the circumstances of our vessel obliged me to renounce the hope I had cherished of seeing at least the mouth and the shore bluffs of the Rio Negro, Santa Cruz, and Gallagos Rivers, and also of visiting the Falklands, I could not connect my observations in San Mathias Bay with any other facts on the eastern coast of Patagonia or its outlying islands. But after rounding Cape Virgens we came into Possession Bay, where the geology along the shore was of a most interesting character. All along the northern shores of the Straits of Magellan the tertiary formation observed on the eastern shore of Patagonia is plainly distinguishable even from a distance by its horizontal beds, which are also visible upon the Fuegian coast. In Possession Bay we landed to examine more closely the character of the country, some of us with the intention of exploring more particularly the terraces above the shore bluffs; while others were bent upon a longer excursion to Mount Azmon and adjoining hills.

About a mile from the shore bluff I found, nearly 150 ft. above the sea level, a salt pool in which, to my great surprise, marine shells identical with those now living along the shore were abundant. They were in a perfect state of preservation, and many of them were alive; so that I gathered a number of specimens with the living animal, which I have preserved in alcohol. The most common were *Mytilus*, *Buccinum*, *Fissurella*, *Patella*, *Voluta*, &c., all found in apparently the same numerical relation as that in which they now exist in the sea below the cliff. The presence of this pool with its living inhabitants shows a very recent upheaval of the coast. The period at which it may have taken place it is hardly possible to determine without a more extensive survey. As the facts stand, it is a most valuable confirmation of Darwin's assertion of recent upheavals on this shore, published more than thirty years ago; though he attributes phenomena to this cause, and connects with it facts which had, in my opinion, a different origin and another significance. At the season of our visit to Possession Bay, in March, when autumn is approaching in this hemisphere, the pool was nearly dry, and the little water left in it was intensely saline. Dr. White has examined it chemically, and handed me the following report of his analysis:—"The specimen of water obtained from the pond at Possession Bay was found to contain magnesia, lime, sulphuric acid, chlorine, a small quantity of iron, and a trace of iodine. It was about 2½ times as dense as ordinary sea water, as shown both by hydrometric observation and by the total amount of chlorine present; organic matter in excess." The shores of the pond showed plainly that in the rainy season it is three or four feet deep, when no doubt the water is more like sea water than at the time of our visit. From the innumerable tracks of guanacos, it must be the constant resort of these animals, and, indeed, during the day we saw many of them moving in that direction. A more palpable evidence of upheaval has not, as far as I know, been observed before. Dead marine shells scattered over dry land are not always conclusive evidence of the former presence of the ocean, for they may have been dropped by birds or other animals; but a salt pond more than 100 ft. above the sea level, with the same shells alive as those now found on the shore, could only be produced by an upheaval. The land beyond the first shore bluff is horizontal. It rises in regular terraces to about 400 ft. above the level of the sea. This is also the general level of the country, the surface of which is much ravined and furrowed. I counted eight such terraces above the beach. They all consist of tertiary deposits; but upon the beach itself three lower levels may be distinguished, their relative age being marked by the presence or absence of vegetation on the sand. Upon the third terrace, a little above and more inward than the salt pool, at the height of at least 150 ft. above the sea, I found a distinct moraine, in which the scratched pebbles were mingled with the simply rounded ones in as large a proportion as in any front moraine in actual contact with a glacier. This moraine was arched, with the convexity turned northward, and the abrupt slope southward, showing that the motive power which had brought and left it there must have moved from the south in a northerly direction. Higher up, to a level of about 400 ft. above tide water, there are also erratics scattered over the plain. At the level of 400 ft.—the highest to which I ascended—I saw a number of large, angular boulders.

Here are facts, then, of great significance in close proximity, namely, a pool containing marine shells alive, more than 100 ft. above the level of the sea, showing a very recent rise of the tract of land it occupied; and an accumulation of pebbles and boulders having all the characters of a glacial moraine, resting upon one of numerous terraces, which seem to mark successive upheavals of the country. That these retreating levels only simulate the successive steps of a gradual upheaval, and are in fact no evidence of such an occurrence, is proved by the geological constitution of the ground, which is entirely made up of regular tertiary beds, without a trace of shore pebbles. Darwin, who has also observed the phenomena of subsidence and upheaval characteristic of this region, was led to believe that the drift was scattered over Patagonia by icebergs while the country was submerged. The moraine upon one of these terraces mentioned above shows, however, that the upheaval must have taken place before the dispersion of the drift, and not after. I say nothing here of Pourtales's very interesting discovery of an extensive field of extinct volcanoes to the north of Possession Bay, of which Mount Azmon is the largest, since he has already sent you an official report on the subject. His observations are among the most valuable results of our geological work. The suggestion presents itself at once that the upheaval of the region may be connected with the former activity of those volcanoes. Throughout the eastern part of the Straits of Magellan the shores exhibited tertiary formations such as we had traced along the Atlantic coast of Patagonia and in San Matthias Bay. Of course in deposits of this kind we could not expect to find any trace of smooth polished rocks.

The last localities of recent geological age which we examined carefully were Elizabeth and Magellan Islands. The latter is almost entirely made up of glacial drift, among which there are a good many large and small boulders with very smooth surfaces and characteristic scratches, and some of them are of the same red porphyry and epidote mentioned before. At Sandy Point large accumulations of boulders are scattered over the whole country, and the streets of the settlement are paved with them. They are easily observed in their natural position on the banks of the river, and in the cuts of the railroad leading to the coal mines. Here the drift is auriferous. Señor Viel, governor of the colony, gave me very fine specimens of the gold collected in the immediate neighbourhood of the settlement. I was also much interested in the coal deposit. There are two considerable seams of coal, one 6 ft. 6 in. thick, and another, 80 ft. higher up, 3 ft. thick. The few species of fossils which I obtained there in great quantity left upon me the impression that the coal is not tertiary, but belongs to the cretaceous formation. The most characteristic of these fossils is an oyster, of the type of the *Ostrea deltoidea*, forming beds many feet in thickness.

After passing Sandy Point the country assumes a completely different aspect. The mountains rise to great heights on both sides of the channel, in consequence of which the region may be compared to the Alps, even though the loftiest peaks, such as Mount Sarmiento, Mount Darwin, Mount Buckland, Mount Barney, only measure from 6,000 ft. to 7,000 ft. But as their base is washed by the ocean, and their slope is very steep, they appear much higher than they really are.

The neighbourhood of Sandy Point will ever be especially interesting to Swiss geologists, from the fact that it recalls many familiar scenes. Pourtales and I greatly enjoyed the comparison with home scenery. In his work on the "Rocks of the Two Hemispheres," and in his "Kosmos," Humboldt repeatedly alludes to the striking similarity of the features exhibited by the inorganic world in regions very distant from each other, and I only follow in his footsteps if I say that Sandy Point and the tracks north of it recalled to me the Jura and the more level country at its foot, while the higher ranges to the south reminded me of the Alps. The comparison might be carried into detail without exaggeration. The first chain in sight from the channel, in which the coal deposits are found, rises only to about 1,000 ft., and resembles the Neocomian hills skirting the western Jura; while the second chain, rising to about 2,500 ft., may be compared to Chaumont, or some other of the less elevated summits of the same range. Even the ravine leading to the coal mine brought back to me the gorges on Seyon, with its torrent; while the flats below stand in the same relation to the hills as the alluvial Pointe du Bied and the tertiary plain of Berex holds to the Jura. This resemblance is not simply superficial; it actually extends to the geological structure of the whole region. The higher mountains to the south, though recalling the Alps, should not be compared with the highest Swiss ranges, such as Mont Blanc, Mont Rosa, or the Bernese Oberland; they have more the character of the Osmonds. Mont Jura, for instance, when seen from the north, reminds one of the Niesen, or some of the conical heights rising above Meilleiries, such as the Cornette de Brise; when seen from the east it may be likened to the Untersberg, near Saltzburg. Mount Sarmiento, Mount Buckland, Mount Barney, and many others less known, have truly the character of the highest Alps. Mount Buckland resembles the Matterhorn very strikingly in form, except that its surface is entirely shrouded in ice.

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* Reprinted from the *New York Tribune*.

It was not till we rounded Cape Froward that I felt confident that the range of hills immediately in sight along the channel we followed had assumed their present appearance in consequence of abrasion by ice. Now, however, that I have seen the whole length of the Straits of Magellan, have passed through Smyth's Channel, and visited Chiloe, I am prepared to maintain that the whole southern extremity of the American Continent has been uniformly moulded by a continuous sheet of ice. Everywhere we saw the rounded undulating forms so well known to the students of glacial phenomena as *roches moutonnées*, combined with the polished surfaces scored by grooves and furrows running in one and the same direction; while rocks of unequal hardness, dykes traversing other rocks, slates on edges, were all cut to one level. In short, all the surface features of the Straits of Magellan have much the same aspect as the glaciated surfaces of the Northern Hemisphere. Whenever the furrows and scratches were well preserved their trend was northern.

I have recorded carefully every locality having a special interest in reference to those facts. I will here only mention a few of the most characteristic ones. The first unquestionable *roches moutonnées* I saw were upon the nearest coast opposite Cape Froward—as the English maps have it—where the rocks are bent and twisted, as those of the Dent du Midi and the Dent de Morchi. Cape Frouart—for such is the French name given by Frezier to the southernmost promontory of the continent—is itself rounded and polished, most especially on its south-west exposure, with rugged crests as above the Grimsel in the Nägeli's Grath. All the hills between Snug Harbor and Wood Bay are equally rounded and polished to their very top. Even the wooded part of the slope shows the characteristic undulations of glaciated hill-sides. Many hills and mountains east and west of Cape Holland exhibited the same aspect. I was particularly struck with the appearance of a gentle slope between Cape Holland and Point Coventry, the surface of which exhibited some naked knolls distinctly glaciated, while the wooded part of the hill had the same form. All these mountains recall the Vor Alps, such as the Moleson, the Faulhorn, the Rhigi, and the Pilates, rather than the Alps themselves, even when entirely covered with *névé* or ice. These rounded knolls and glaciated surfaces penetrate frequently into the narrow coves which open into the main channel, in a north-south direction, at right angles with the Straits themselves—thus showing that the grinding agent must have moved from the south northward or from the north southward, and not from east to west or from west to east, as the Straits mainly trend. In Port Gallant, I saw large and small pebbles, and large boulders, many at least 6 ft. in diameter, and one measuring 12 ft. by 6 ft. and 5 ft., well rounded, and more or less polished, with rectilinear scratches in different directions all over their surface—in fact, such as are only found in genuine ground moraines.

The whole of Fortescue Bay, with the exception of a small land beach, on which we found a Fuegian camp, is covered with erratics. Even within high and low water mark many pebbles still show glacial scratches, though they are constantly tossed to and fro by the tides. Pourtales had the good fortune to be the first to see genuine glacier scratches, above Port Gallant, upon polished rocks in place. It was upon the surface of a quartz dyke traversing talcose slate. The trend of the scratches was west-north-west. There are *roches moutonnées* all the way from Fortescue Bay to Jerome Point, Cross Mountain included. Jerome Point itself is well polished, especially on the south side. York River Valley, which trends northward, is also well polished on both sides. Between the last two ranges of Jerome Point, westward, there is a cove trending northward, in which the *roches moutonnées* are as characteristic as upon the sides and face of the whole Point. The gorge opposite is equally *moutonnée* on both sides, showing that the denudation has not yet been the work of an agent moving east-west or west-east through the main channel. The two heads of the narrowest part of the straits (El Morion and Cape Gnod) are beautifully polished and rounded. The last range of Jerome Point seems to show that the abrading cause acted from S.S.W. to N.N.E. In Borgia Bay the ground is covered with large pebbles and boulders, some of the largest of which are rounded, polished, and scratched. Pourtales and Kennedy ascended the peak marked 1,923 upon the Admiralty map of Borgia Bay, and found *roches moutonnées* to the height of about 1,500 ft., while higher up the rocks were broken into rugged ridges. The whole scenery reminded me of the Abschwartz, above the glacier of the Aar. Some of the polished surfaces resembled, in the most surprising manner, places represented in my works upon the glaciers, and might have served as models for the illustrations I published of the glacial phenomena in Switzerland more than thirty years ago. No promontory in the whole extent of the straits, seen from either its eastern or its western side, shows as probable a strike-side of the polishing agent as the north and south exposures; leading to the presumption that the planing-machine has moved north and south, even though every surface seems almost equally well polished. Nothing indicates the fitful action of icebergs. Glacier Bay has also been for me a most fruitful field of study; but of this more in detail later. In the harbour of Sholl Bay there are several concentric moraines marked by boulders and kelp, which may have been deposited by the great glacier on the opposite side of the channel.

With all the evidences of glacier action constantly before our eyes, the journey from Cape Frouart to Cape Tamar was nevertheless tantalising to me, because it gave no opportunity for tracing the facts in unbroken continuity. The course of the Straits of Magellan bearing mainly in an east-westerly direction cuts everywhere at right angles, the effects produced by the southern ice-shoes upon the solid foundation of the whole track. Only after we had rounded Cape Tamar and passed Sholl Bay did we enter a channel bearing in the same direction with the glacial erosion, and thus affording an opportunity of following connectedly on the opposite sides of the whole channel, as far as the Gulf of Pennas, the traces left by glaciers upon the surface of the rocks. Here, as in reference to the Straits of Magellan, I shall describe only such localities as have a marked interest, reserving more details for another occasion. The facts spoke so plainly that even those not familiar with them were struck by their distinctness. Following the inside route through Smyth's Channel to the Gulf of Pennas, we were all the way within touching distance of the rocky walls of those narrow passages, so that nothing could escape us, and as the intricacy of the channels forebade travelling by night, we lost nothing in that way.

The Andes proper begin at Cape Providence, within the Straits of Magellan, but their alpine character is not strikingly developed south of Union Sound, even though at the bottom of Glacier Sound very high mountains with large glaciers may be seen. Mount Burney may be compared to Mount Sarmiento; still, throughout Smyth's Channel, until coming into Collingwood Strait, through Victory Pass, the scenery is very much like that of the Straits. In the southern parts of Smyth's Channel, I for the first time noticed un unmistakable difference between the southern and northern exposures of the nearer ranges trending N.S. Here it became every hour more plain that the strike-side of the glacial agency was upon the southern slope, and the lee side upon the northern. As soon as the Cordillera of Sarmiento opens into view the grandeur of the range is fully displayed. From the highest mountains glaciers depend to the sea level, which may be fairly compared to the most impressive glaciers of Switzerland. Throughout this region, as well as in other parts of the Straits, the nomenclature of the islands and mountains, as adopted upon the Admiralty chart, has a character very pleasing to a scientific man, and very creditable to those who have wished to connect the memory of their distinguished contemporaries and friends with their own investigations. Indeed, the names of all the prominent men of England, distinguished for their devotion to science thirty-five or forty years ago, form now a part of the physical geography of these regions. With these are associated some foreign names which, however, are not always so happily applied, very eminent names being, in some instances, given to very insignificant localities. We had twice a beautiful view of Mount Burney; first coming up through Mayne Channel, where we had an opportunity of seeing the vast difference between its aspect when covered with snow to the very base, as represented by Dr. Cunningham, and as we saw it, with its upper part only shrouded in perpetual snow and ice. It will be long before the real level of perpetual snow is ascertained in these regions, as any boisterous day may change the appearance of a mountain range to an astonishing degree. The mountains to the north of Cape Providence, Mount Burney, the Cordillera of Sarmiento, and the mountain ranges east and north of Snowy Glacier, form part of one and the same chain, and are in reality the southern termination of the Andes. L. AGASSIZ

(To be continued.)

ON THE SPECTRUM OF THE GREAT NEBULA IN ORION, AND ON THE MOTIONS OF SOME STARS TOWARDS OR FROM THE EARTH[*]

IN my early observations of the spectrum presented by the gaseous nebulæ, the spectroscope with which I determined the coincidence of two of the bright lines respectively with a line of nitrogen and a line of hydrogen, was of insufficient dispersive power to show whether the brightest nebular line was double, as is the case with the corresponding line of nitrogen.

Subsequently I took some pains to determine this important point by using a spectroscope of greater dispersive power. I found, however, that the light furnished by the telescope of eight inches aperture, to which the spectroscope was attached, was too feeble, even in the case of the brightest nebulæ, to give the line with sufficient distinctness when a narrow slit was used. The results of this later examination are given in a paper I had the honour of presenting to the Royal Society in 1868. I there say[†]:—

"I expected that I might discover a duplicity in the line in the nebula corresponding to the two component lines of the line of nitrogen, but I was not able, after long and careful scrutiny, to see the line double. The line in the nebula was narrower than the double line of nitrogen; this latter line may have appeared broader in consequence of irradiation, as it was much brighter than the line in the nebula." When the spark was placed before the object-glass of the telescope, the light was so much weakened that one line only was visible in the spectroscope. "This line was the one which agrees in position with the line in the nebula, so that under these circumstances the spectrum of nitrogen appeared precisely similar to the spectra of those nebulæ, of which the light is apparently monochromatic. This resemblance was made more complete by the faintness of the line; from which cause it appeared narrower, and the separate existence of its two components could no longer be detected. When the line was observed simultaneously with that in the nebula, it was found to appear but a very little broader than that line." I also remark:—"The double line in the nitrogen-spectrum does not consist of sharply defined lines, but each component is nebulous, and remains of a greater width than the image of the slit.[‡] The breadth of these lines appears to be connected with the conditions of tension and temperature of the gas. Plücker states that when an induction-spark of great heating-power is employed, the lines expand so as to unite and form an undivided band. Even when the duplicity exists, the eye ceases to have the power to distinguish the component lines, if the intensity of the light be greatly diminished." I state further:—"I incline to the belief that it [the line in the nebula] is not double."

One of the first investigations which I proposed to myself when, by the kindness of the Royal Society, I had at my command a much more powerful telescope, was the determination of the true character of the bright line in the spectrum of the nebula, which is apparently coincident with that of nitrogen. From various circumstances, chiefly connected with the alterations and adjustments of new instruments, I was not able to accomplish this task satisfactorily until within the last few months.

Description of Apparatus

It seems to me desirable to give a description of the spectroscopic apparatus with which the observations in this paper were made. In the former paper, to which I have already referred, I gave some reasons[*] to show that the ordinary method of comparison, by reflecting light into the spectroscope by means of a small prism placed before one half of the slit, is not satisfactory for very delicate observations unless certain precautions are taken. I then describe an arrangement for this purpose, which, with one or two modifications, is adopted in the collimator constructed for use with the Royal Society's telescope. I give the description from that paper[†]:—

"The following arrangement for admitting the light from the spark appeared to me to be free from the objections which have been referred to, and to be in all respects adapted to meet the requirements of the case. In place of the small prism, two pieces of silvered glass were securely fixed before the slit at an angle of 45°. In a direction at right angles to that of the slit, an opening of about $\frac{1}{10}$ inch was left between the pieces of glass for the passage of the pencils from the object-glass. By means of this arrangement, the spectrum of a star is seen accompanied by two spectra of comparison, one appearing above, and the other below it. As the reflecting surfaces are about 0·5 inch from the slit, and the rays from the spark are divergent, the light reflected from the pieces of glass will have encroached upon the pencils from the object-glass by the time they reach the slit, and the upper and lower spectra of comparison will appear to overlap to a small extent the spectrum formed by the light from the object-glass. This condition of things is of great assistance to the eye in forming a judgment as to the absolute coincidence or otherwise of lines. For the purpose of avoiding some inconveniences which would arise from glass of the ordinary thickness, pieces of the thin glass used for the covers of microscopic objects were carefully selected, and these were silvered by floating them upon the surface of a silvering solution. In order to ensure that the induction-spark should always preserve the same position relatively to the mirror, a piece of sheet gutta-percha was fixed above the silvered glass; in the plate of gutta-percha, at the proper place, a small hole was made of about $\frac{1}{20}$ inch in diameter. The ebonite clamp containing the electrodes is so fixed as to permit the point of separation of these to be adjusted exactly over the small hole in the gutta-percha. The adjustment of the parts of the apparatus was made by closing the end of the adapting-tube, by which the apparatus is attached to the telescope, with a diaphragm with a small central hole, before which a spirit-lamp was placed. When the lines from the induction-spark, in the two spectra of comparison, were seen to overlap exactly for a short distance the lines of sodium from the light of the lamp, the adjustment was considered perfect. The accuracy of adjustment has been confirmed by the exact coincidence of the three lines of magnesium with the component lines of *b* in the spectrum of the moon."

The modifications of this plan consist in the substitution of a thin silver plate polished on both surfaces for the pieces of silvered glass. The opposite side of the silver plate to that from which the terrestrial light is reflected to the slit reflects the images formed by the object-glass to the side of the tube where a suitable eye-piece is fixed. This arrangement forms a very convenient finder, for it is easy to cause the image of the star to disappear in the hole in the silver plate. When this is the case the line of light formed by the star falls on the slit, and its spectrum is visible in the spectroscope. This collimator is so constructed that, by means of a coupling screw, any one of three spectroscopes can be conveniently attached to it.

This apparatus performs admirably; but it seemed to me desirable, for observations of great delicacy, to be able to dispense with reflection, and to place the source of the light for comparison directly before the slit. Formerly I accomplished this object by placing the spark or vacuum-tube before the object-glass of the telescope. The great length of the present telescope renders this method inconvenient; but a more important objection arises from the great diminution of the light when the spark is removed to a distance of 15ft. from the slit. I therefore resolved to place the spark, or vacuum-tube, within the telescope at a moderate distance from the slit. For this purpose holes were drilled in the tube opposite to each other, at a distance of 2ft. 6in.

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[*] By William Huggins, LL.D., D.C.L., F.R.S. Paper read before the Royal Society, June 13, 1872.

[†] Phil. Trans. 1868, pp. 542, 543.

[‡] Phil. Trans. 1863, p. 13.

[*] Phil. Trans. 1868, pp. 537, 538.

[†] Phil. Trans. 1868, p. 538.